Journal of Asian Earth Sciences 61 (2012) 116–127

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Regional variations in the lead isotopic composition of galena from southern Korea with implications for the discrimination of lead provenance

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ARTICLE INFO

Article history:
Received 22 May 2012
Received in revised form 4 September 2012
Accepted 17 September 2012
Available online 27 September 2012

Keywords:
Galena
Ore
Lead isotope
Korea
Provenance

ABSTRACT

This study presents a comprehensive database (n = 215) of lead isotopes in galena from the southern Korean peninsula using new and published data. Of the 69 metal mines examined, predominantly skarn- and hydrothermal-type Pb–Zn–Au–Ag–Cu deposits were observed and were associated with Mesozoic magmatic activities. Galena samples from each geotectonic unit showed discrete lead isotopic signatures. The Gyeongsang basin samples were characteristically unradiogenic and had restricted variations in lead isotopic composition ($^{206}Pb/^{204}Pb$ = 18.16–18.59, $^{207}Pb/^{204}Pb$ = 15.48–15.64, $^{208}Pb/^{204}Pb$ = 37.87–38.77). Their $^{208}Pb/^{204}Pb$ range indicated an involvement of source materials less thorogenic than the associated granites. The galena samples from Cambro–Ordovician carbonate rocks of the northeastern Yeongnam massif and eastern Taebaeksan basin had the most radiogenic $^{206}Pb/^{204}Pb$ (19.28 ± 0.14) and $^{207}Pb/^{204}Pb$ (15.833 ± 0.027) ratios. Their lead isotopic trend indicated a combined contribution of ore lead from granitic magmas, Precambrian basements, and overlain host rocks. Less radiogenic galena samples from the middle to southwestern parts of the Yeongnam massif and Okcheon belt showed limited lead isotopic variations ($^{206}Pb/^{204}Pb$ = 18.332 ± 0.065, $^{207}Pb/^{204}Pb$ = 15.693 ± 0.012, $^{208}Pb/^{204}Pb$ = 38.93 ± 0.07 on average), probably resulted from mixing with a common crustal basement. The differences in lead isotopes between the radiogenic and unradiogenic groups from the Yeongnam massif and Okcheon belt may reflect the spatial dissimilarity of involved crustal rocks. The old crust appears to have significantly contributed ore lead to galenas from the western Gyeonggi massif, but the geochronological meaning of their steep $^{207}Pb/^{204}Pb$–$^{206}Pb/^{204}Pb$ trend is not clear. The comprehensive database constructed by the present study suggests that lead province in the southern Korean peninsula may be subdivided into four discrete zones. Linear discriminant analysis showed that more than 90% of the compiled data were correctly reclassified within their a priori zones. Such discrimination may be useful for a wide range of applications, including mineral exploration, archaeological correlation, and environmental characterization.

1. Introduction

Common lead isotopic compositions in ore minerals have evolved in crustal and mantle reservoirs with largely different U, Th, and Pb contents (Doe and Zartman, 1979; Zartman and Doe, 1981; Zartman and Haines, 1988). The initial isotopic composition of lead withdrawn from the reservoirs is well recorded in galena because no uranium or thorium is incorporated into the galena crystal structure after its formation. These "frozen" isotopic signatures in galena have been widely used in explorations for various metallic ore deposits (Gulson, 1986), considering that lead in hydrothermal fluids behaves similarly to other metals, particularly zinc, silver, and copper (Wood et al., 1987; Hemley et al., 1992). The lead isotopes in galena are also useful for archaeological correlation between metal artifacts and the ore source (Gale and Stos-Gale, 2000), as well as for characterizing lead in environmental samples (Mukai et al., 1994).

Early studies on the lead isotopic composition of ore lead (Mabuchi, 1985; Sasaki, 1987) suggested that the metallogenic province of the Korean peninsula may be subdivided into several domains. Since this finding is crucial for mineral exploration and provenance research, further detailed investigation is warranted. This study presents a comprehensive lead isotopic database for ore galenas from the southern Korean peninsula to firmly establish the validity of provenance discrimination. The origin of lead is

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http://dx.doi.org/10.1016/j.jseaes.2012.09.008

discussed by comparing our compiled data with previous results reported for the host rocks of the ore bodies and associated granitoids.

2. Geological background and sample collection

As shown in Fig. 1, the southern part of the Korean peninsula is composed of four northeast-trending geotectonic provinces. The two Neoarchean to Paleoproterozoic massifs (Gyeonggi and Yeongnam) mainly consist of high-grade metamorphic rocks with intervening by the Neoproterozoic to Paleozoic Okcheon fold belt. The Okcheon belt is further divided into the Taebaeksan basin to the northeast and the Okcheon metamorphic belt to the southwest. The southeastern part of the peninsula forms a Cretaceous to Paleogene arc system composed of an arc platform and a backarc basin (Gyeongsang basin) (Chough and Sohn, 2010). Widespread occurrences of granitic rocks from the Late Permian to Paleogene (Cheong and Kim, 2012) are generally believed to be related to the subduction of the paleo-Pacific plate. Refer to Chough et al. (2000) for a comprehensive review of Korean geology.

We collected 141 galena samples from 38 metal mines. Most of them are currently abandoned or closed. Lead isotopic analyses of these new samples, supplemented by data from previous studies, provided an ample database composed of 215 data points from 69 mines in total. The locations of the examined mines are shown in Fig. 1. The ore type, host rocks, ore and associated minerals, and previous dating results are briefly described in Table 1. This summary indicates that the majority of metallic ore deposits in South Korea are skarn- and hydrothermal-types, which are associated with the Mesozoic magmatic activities. The hydrothermal-type in Table 1 includes the vein, fissure-filling, and replacement deposits.

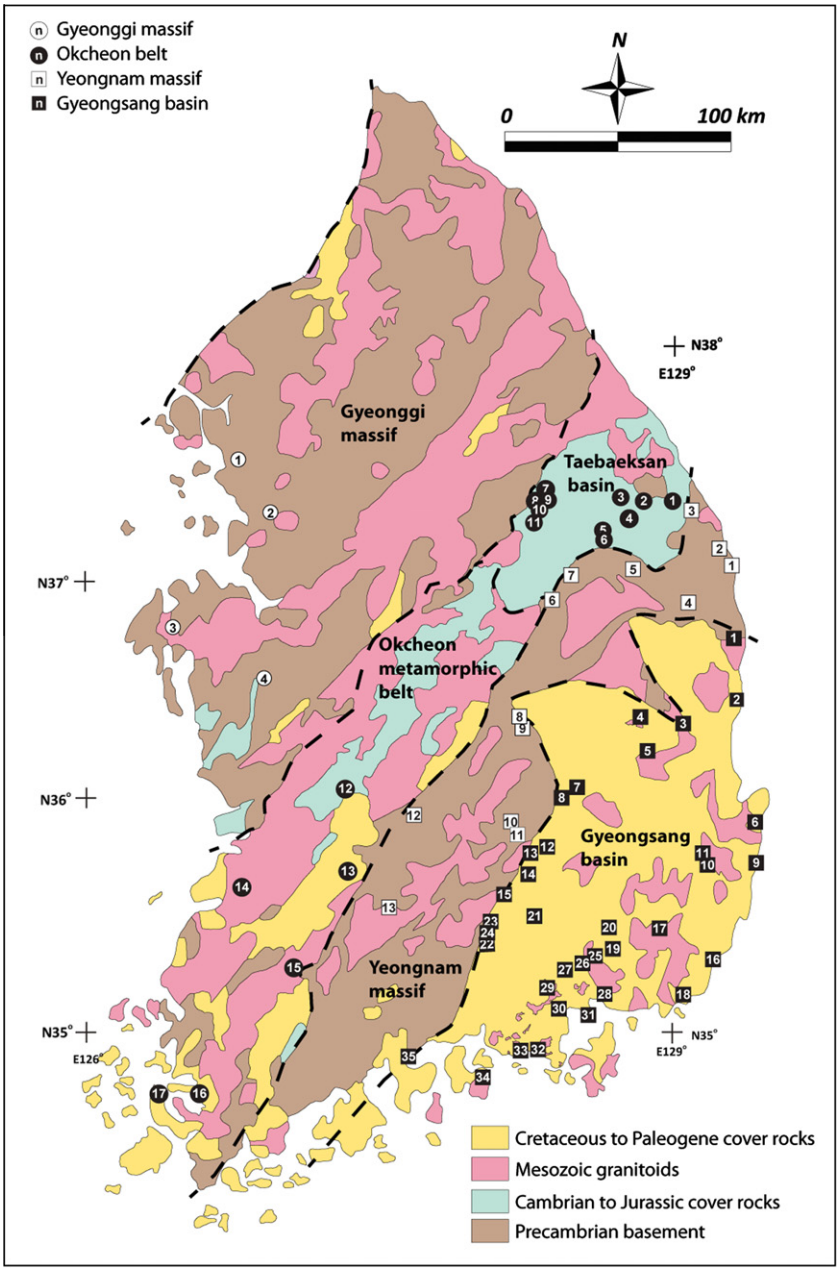

Fig. 1. Simplified geologic map (modified after Chough et al., 2000) showing locations of the examined mines in the southern Korean peninsula. Dashed lines represent boundaries between the geotectonic units.